[redacted] TYPE 586 LENS TESTING BENCH SPECIFICATIONS Dated: December 1958

I. SCOPE

1.1 This specification covers fabrication of one particular type of versatile and precision lens testing bench.

II. REQUIREMENTS

2.1 DESIGN:

This lens testing bench shall be a versatile and precision lens testing bench and its construction of such accuracy that all measured defects of imagery are due solely to the objective lens under test. It shall be of the nodal slide type and provided with flat field bars. It shall accomodate lenses of all focal lengths up to 1220 mm and diameters from .5 inch to 7 inches. It shall include provisions for centering and revolving the lens under test, and the microscope shall be capable of being moved in three mutually perpendicular planes through calibrated micrometer screws. The microscope shall be capable of rotation about its object point through an angle of 100 degrees and also permit testing of telephoto lenses and lenses having extreme distortion.

2.2 MATERIALS AND CONSTRUCTION (General):

The lens testing bench shall include but is not limited to the following major parts:

2.2.1 Carriage lens holder, complete with nodal slide and adjustments (Parts 1-10).
2.2.2 Carriage inspection, complete with microscope and adjustments (Parts 12-19).
2.2.3 Bench base and support (Parts 20-31).
2.2.4 Camera Attachment.

2.3 MATERIALS AND CONSTRUCTION (Detail):

2.3.1 On the front end shall be a bearing whose axis is vertical and on which the nodal slide (1) and independent focal length slide assemblies (2) rotate. The mechanism for holding the lens (5-10) shall be attached to the nodal slide which permits placing the nodal point of the lens over the axis of rotation.
2.3.2 While manufacturing this bench, modern ball bearings shall be used to insure free movement of parts in the desired direction only and to eliminate lost motion. Wherever possible, light weight alloys shall be used to reduce loading on ball bearings.
2.3.3 In order that the measurement of focal length, variation from a flat field and distortion may be made to the accuracy desired, the errors

in construction, and of the measuring means, shall be kept to less than .01 mm.

2.3.4 The bed shall be supported on two columns (23), in such a manner that the front end rests on a ball and socket joint, and the rear end rests on two leveling screws. Also at this point shall be a pair of opposing screws (30), which permit rotation of the bed in a horizontal plane through an angle of 1 degree so that precise alignment can be obtained when employing a collimator. This requires that the ball and socket joint is placed in line with the axis of rotation of the nodal slide in order to make possible this adjustment about the nodal point of the lens.

2.3.5 The bed itself shall be of cast iron fully normalized before the final planning. The ways of the bed shall be the V and flat type, hand scraped to insure straightness and freedom from twist.

2.3.6 The front end of the bed shall be machined to receive the nodal assembly in such a manner that its axis is perpendicular to the longitudinal plane of the ways of the bed.

2.3.7 The nodal slide assembly shall be mounted directly on a heavy steel spindle, which turns on a preloaded ball bearing. It shall be provided at its upper end with a circle (22) and vernier reading to minutes, and its lower end with a worm wheel. The worm for driving this worm wheel shall carry a splined shaft extension (24), which has to be housed in a channel lengthwise in the side of the bed.

2.3.8 The hand wheel assembly (25) for driving the spline shaft shall be constructed such that it can be clamped at any point along the bed within easy reach of the operator.

2.3.9 For rigid construction and to attain free movement with no lost motion, the nodal slide and focal length slide shall be of hardened steel and ball bearing construction. They shall be actuated by rack and pinion drives (3 and 4), with coarse and fine motion.

2.3.10 The nodal slide travel shall be so proportioned as to permit the examination of any telephoto lens whose nodal point lies within 100 mm in front of the lens mount.

2.3.11 Carried on a bridge (5) over the nodal slide shall be an independent centering slide (6), upon which the lens holding mechanism shall be mounted. It shall consist of a hardened and ground ring (9) whose curved outer edge fits into the concaved grooves which shall be ground into the outer races of three ball bearings (8). The positions of the two lower rollers shall be fixed, and the top roller should be provided with an adjustment (7) for setting the axis of rotation of the ring parallel to the horizontal plane of motion of the microscope carriage along the bed. This rotatable ring shall be provided with a graduated circle reading to a half degree. This will be very helpful in optically centering lenses and rapidly examining various sectors in the field of an objective. For use with this lens ring shall be a number of interchangeable sets of radially adjustable lens holding jaws (10). The assembly shall be sturdy enough to hold any lens up to 3 1/2 inches in diameter and weighing approximately five pounds. For holding larger lenses, there shall be available a second ring having tapped holes to which lens mounts may be secured.

2.3.12 The bench shall employ the flat field bar principle for the connection of the focal length slide with the microscope carriage. Part (11) and (14) in the attached drawing indicate the arrangement of the bar, connecting the lens holder with the microscope carriage. Three flat field bars of 60, 100 and 160 cm in length shall be supplied to conveniently cover the range of focal length accomodated by the bench. One bar would cover all cases except those lenses of very short focal lengths. However, the selection of a suitable bar shall make it possible to have the collimator placed nearer the bench than normally used. These bars shall provide automatically a flat field for the observing microscope to follow upon rotation of the nodal slide. The microscope carriage shall contact the bed at 3 points by means of ball bearings used as rollers.

2.3.13 A projection (13) in front of the microscope carriage shall carry a ball bearing roller (12) contacting the side of a steel rod inlet into the face of the flat field bar (14).

2.3.14 At zero focal length, the axis of this roller shall be in exact coincidence with the axis about which the nodal slide rotates. This coincidence shall be effected by adjusting the microscope carriage rollers through eccentric bushings provided for this purpose. Constant contact shall be maintained between the face of the flat field bar and its ball bearing follower through the use of a counter weight (31) which shall be suspended from one end of the bench by a pulley system and attached to the carriage by a flexible cord (20). This flexible cord shall be a twin conductor, rubber covered cable which also shall serve as a lead for supplying electrical power to a small lamp. This lamp shall be the illuminator for a scale reading microscope (27) mounted to the side of the microscope carriage. It shall be used to read the precision focal length scale (28) mounted on the side of the bed. The bench shall be equipped with two focal length scales, one of which shall be a coarse scale, (29) graduated in millimeters and numbered every tenth millimeter. It shall be read from an engraved line index on the microscope carriage to the nearest millimeter. The precision scale shall be diamond ruled with graduations every millimeter. It shall be read to one-hundredth of a millimeter in conjunction with a reticle in the scale reading microscope to permit measurements to be made as specified in section 2.3.3.

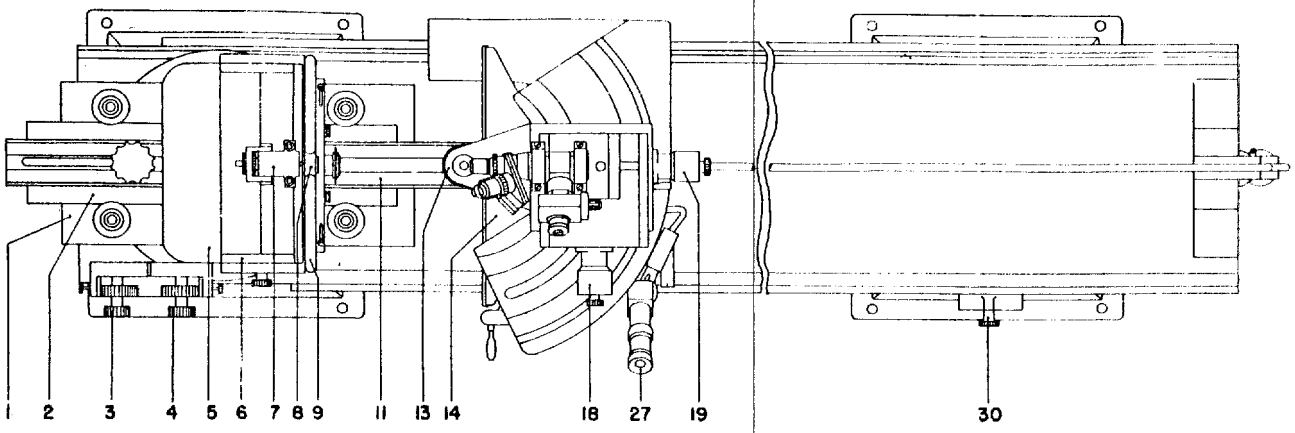
2.3.15 At the top of the microscope carriage shall be a plate (13) pivoted over the axis of the flat field bar follower. Mounted on this plate shall be ball bearing slides moving in three mutually perpendicular planes. The observing microscope carried by these slides shall be focussed on a point coincident with the axis of rotation of the plate and the flat field bar follower. The motion of the microscope about this axis in a horizontal plane shall be possible through a total angle of 100 degrees and shall be read directly on a sector of a circle graduated in half degrees.

The microscope ways shall be actuated by micrometer screws (17, 18, 19) graduated to read in hundredths of a millimeter, with sufficient motion to measure the most severe cases of curvature of field and distortion likely to be encountered; the precision of graduations of the micrometer screws shall not limit the overall precision of the bench. The microscope shall be equipped with three eyepieces of four, six and ten times magnification and a filar eye-piece (16) of standard design. Four parfocalized objectives (15) whose effective focal lengths shall be 32, 16, 10 and 4 millimeters in a quadruple nose piece shall provide a range of magnification suitable for all purposes. All eye-pieces shall be equipped with crosshairs and all optical elements shall be provided with reflection reducing coatings. The ocular shall be inclined to the tube for convenience in viewing the image under inspection.

2.3,16 A 35mm camera shall be attached to a tube which would replace the microscope. The tube shall be wide enough to hold a microscope lens inside on an axially adjustable tube.

III. MATERIAL AND MECHANICAL REQUIREMENTS

3.1 The design and fabrication of all optical and mechanical elements shall be of highest quality workmenship and consistent with the most recent optical and related principles available and shall incorporate such characteristics and quality as required for lens testing bench tests of very high accuracy and high precision of measurement.



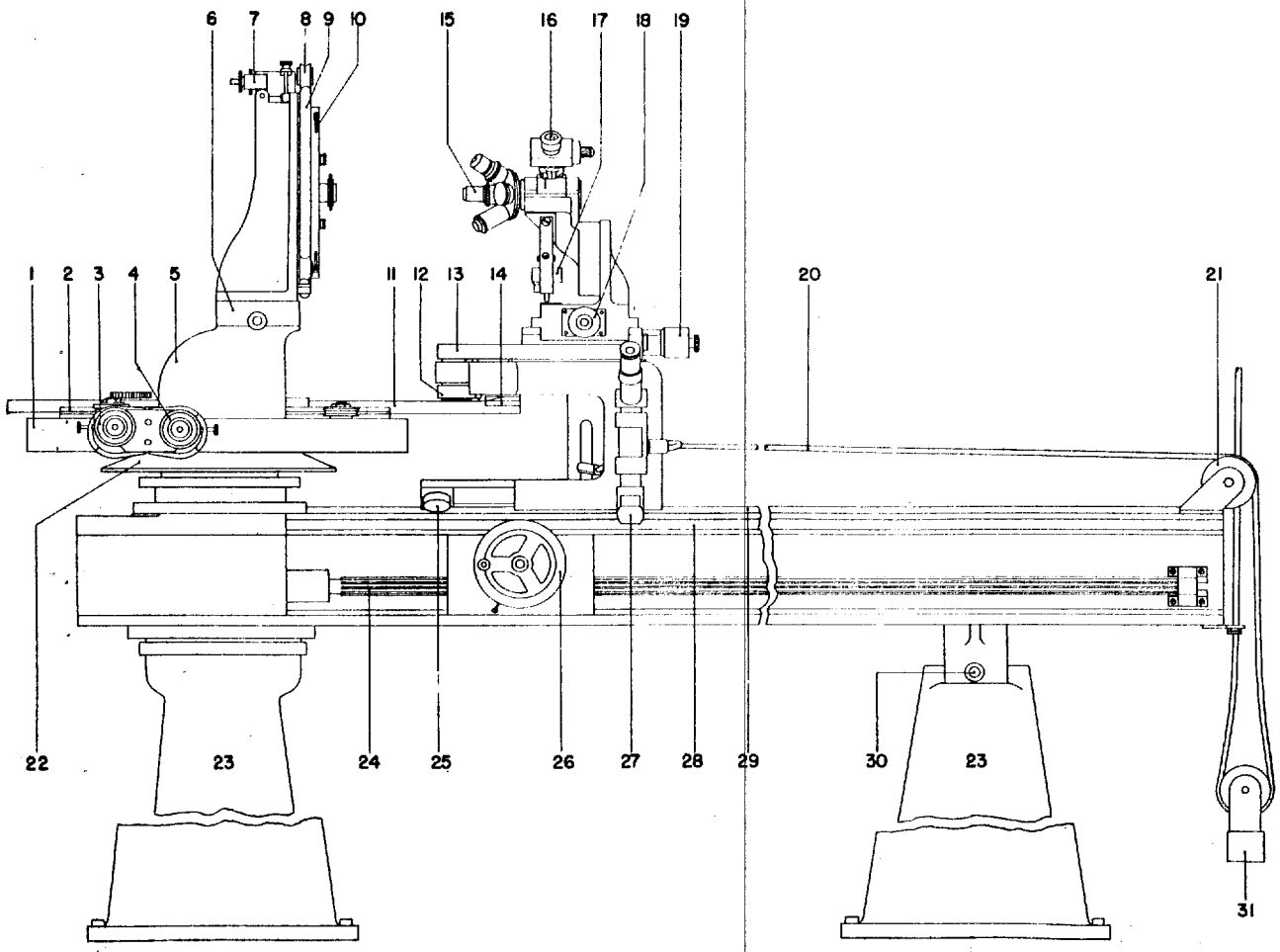


Figure 1

Plan and Elevation Views of Lens Testing Bench

LEGEND FOR FIGURE 1

1. Nodal Slide
2. Focal Length Slide Assembly
3. Drive for focal length slide ($\frac{\text{fast}}{\text{slow}} = \frac{4}{1}$)
4. Drive for nodal slide ($\frac{\text{fast}}{\text{slow}} = \frac{4}{1}$)
5. Bridge
6. Centering slide and screw (carries lens board)
7. Adjustment for upper bearing of lens board
8. Ball bearing support for lens board
9. Lens Board (1/2° divisions)
10. Lens holding jaws (Scroll adjustment)
11. Blade of flat field bar
12. Flat field bar guide roller
13. Plate, supports microscope assembly & pivots about axis of guide roller.
14. Head of flat field bar
15. Microscope Objectives
16. Microscope Eyepieces
    Filar micrometer and other eyepieces interchangeable
17. Micrometer screw (.01 mm) X-coordinate, 12 mm of travel
18. Micrometer screw (.01 mm) X-coordinate, 25 mm of travel
19. Micrometer screw (.01 mm) Y-coordinate, 30 mm of travel
20. Power cord for microscope illumination, also tension cord for microscope carriage.
21. Pulley for tension cord

LEGEND FOR FIGURE 1 (cont.)

22. Circle & vernier, rotation about nodal axis (reading to minutes).

23. Pedestals

24. Splined shaft (rotates nodal spindle)

25. Microscope carriage support rollers

26. Handwheel for rotating nodal slide

27. Microscope for reading focal length scale

28. Precision focal length scale

29. Coarse focal length scale

30. Opposing screw for aligning bed parallel to collimator axis.

31. Weight & pulley for tension on cord